

The Prevention and Amelioration of Saline and alkali soils in China

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In China, saline-alkali lands are distributed broadly among dry and semi-dry areas. The saline-alkali lands were formed by the comprehensive influences of special climate, hydrogeology and other natural conditions. Before 1949 there was more than 26.7 million ha of saline-alkali area in China, in which more than 6.6million ha were saline-alkali farmland. After fifty-year development of water conservation and basic construction of farmland, 60 % of the saline-alkali farmland has been improved in various extents. However, among the saline-alkali farmland in China, there is still large area of medium and low yield farmland need to be further improved and ameliorated. To maintain a favorable and sustainable condition for agricultural production, the measures have to be taken to protect irrigation farmland from secondary soil salinization.

1. The causes and distribution of salt affected area in China

1.1 Causes of soil salinization

The salt affected area was formed by the combining influence of climate, landform, hydrogeology and soil properties, etc. There are both common and individual characters for the formation of salt affected areas in different regions. In the Huang-Huai-Hai plain in China, drought, waterlogging and soil salinization occur frequently due to the monsoon climate, concentrated rainfall, high evaporation, low-lying and flat landform, poor drainage condition and poor soils. These are the basic factors to induce the unstable agricultural production in the area. In the inland region in northwest China, the farmland is located at the river alluvial plain with high landform, deep groundwater tables and good groundwater flow condition. At the initial development stage, only irrigation systems were developed without drainage facilities. After running for several years, shallow groundwater tables were caused by excess recharge from canal seepage and flood irrigation. The shallow groundwater tables further induced serious soil salinization and marshland at the low reaches of irrigation districts. In the coastal areas, saline-alkali soils were induced by the high initial salt content in soils, high salinity of groundwater, poor drainage condition and inadequate measures for soil amelioration. In some areas, secondary soil salinization was also induced by long term irrigation with low salinity water.

1.2 Distribution of salt affected area in China

The total saline and alkali area in China is about 26.7 million ha with following classification:

a. The inland drought saline-alkali zone in northwest China, including most of Xinjiang autonomous region, the Chadamu Basin of Qinghai province, the Hexi Corridor of Gansu province and a part of west Inner Mongolia autonomous region. These regions are with continental climate condition; the annual precipitation ranges from 100 to 300 mm. Therefore, in these areas without irrigation implies no agriculture. Groundwater table in the areas range from 3 to 10m below surface and some districts with groundwater table of 1-2m below surface. The salinity of groundwater is generally from 3 to 5 g/l with the highest of more than 10g/l in some regions. The main salts in soil are sulphate and chloride. The salt content in soil within 1 meter below surface is about 1-4%. The salt content in the surface soil can reach as high as 20%.

b. The semi-arid saline-alkali zone at middle reaches of the Yellow River, including the Qinghai province, the eastern part of Gansu province, the Ningxia autonomous region, the Hetao Area of Inner Mongolia autonomous region and the river valley plain in Shaanxi and Shanxi provinces. The landforms in these areas are complicated and drought occurs frequently with many windy days in a year. The annual precipitation is from 150 to 400 mm with unfavorable drainage condition in the areas. Saline-alkali soils are distributed in strips on the alluvial plain of Yellow River and loess plateau.

c. The semi-arid and semi-humid low-lying saline-alkali zone in the Huang-Huai-Hai plain, including low areas beside the lower reaches of the Yellow River, the Haihe plain and the Huang-Huai plain, covering Beijing, Tianjin cities, and Hebei, Shandong, Henan provinces, North Anhui and North Jiangsu plain area. This region is the broadest plain with the high reclamation rate and the high population density in China. The annual precipitation in the area is increased from 400mm to 800mm from north to south. About 70% of the annual precipitation are concentrated in the period from June and September with obvious variation among years. Soil is river alluvial accretion with light texture and clear layer sequence. Besides the main salts of sulphate and chloride, there is also the carbonate in some areas. The groundwater tables are rather shallow, usually 1-3 m below the surface. The salinity of groundwater is generally 2-5 g/l with the highest of more than 10g/l. Due to the gentle surface slope, drainage condition for both surface water and groundwater are impeded. Drought, waterlogging and soil salinizations coexist and interact one another in the area.

d. The semi-humid and semi-arid low-lying zone in northeast China, including the Songnen plain, the West Liaohe basin, the Sanjiang plain and the Hulunbeier region, covering the low plain of Liaoning, Jilin and Heilongjiang provinces. The area is with gentle surface slope and humid climate. The annual precipitation ranges from 500 to 700 mm. The groundwater table is about 2 m below the surface with general salinity from 2 to 5 g/l and highest of 10g/l. The salt content in saline-alkali lands is usually below 0.3% with bicarbonates and carbonates as the main salts.

e. The semi-humid saline-alkali zone in coastal areas, including coastal area at north Yangtze River. The area is tide influenced coastal area with flat landform. The annual precipitation in the area is about 1000mm in south and 600 mm in north with monsoon influence. The groundwater level is from 0.5 to 2.5 m below the surface with salinity over 10g/l. In some place, the salinity of groundwater is higher than 50g/l. The average salt content in soil within 1m below surface is over 0.4% with highest up to 5%. The main salt in soil is chloride.

2. The amelioration of saline and alkali lands and prevention of secondary soil salinization

In China, the amelioration of saline and alkali lands has experienced a long history of development. It was said that the Emperor Great Yu in Xia Dynasty (2200 B.C.) in his great work of water control had practiced the so-called "Ditch regime" as the network of irrigation and drainage. At that time saline and alkali soils were already considered as a factor for the classification of land and agriculture production region (Yu Gong). In order to promote agricultural production, the ancient working people had built canals and diverted water from rivers for irrigation. Furthermore, they also had practiced the saline-alkali land amelioration by leaching salts with flood irrigation. For example, at 246 B.C., the Qin state built the Zhengguo Canal in present Shanxi Province to divert the silt-laden water from Jing River to irrigate the saline land of more than 130 thousand ha (Shii. River

and Canal Volume). More early, at 300 B.C., the Wei state diverted water from Zhang River in present Hebei Province to reclaim the saline land and grow paddy rice (Hanshu, Ditch regime). Therefore, in China with the development of irrigated agriculture in thousands years, the saline and alkali lands have been gradually ameliorated and utilized.

At that time, the people's recognition and knowledge were limited although they had practiced the reclamation of saline and alkali lands with irrigation measure for a long time. They paid much more attention to irrigation and neglected drainage, especially the importance of subsurface drainage on saline and alkali lands improvement. As a result, secondary soil salinization was occurred in some irrigation districts, which induced the reduction of agricultural productivity of the irrigated farmlands. Fortunately, at that time population density was low in China, people could give up salinized farmlands and develop new farmlands. They could also adopted flood irrigation to wash away salts in soils. However, with the incremental rate of land reclamation, the above two alternatives could not be used anymore. It was proved that in the dry area, agriculture could not exist without irrigation, and sustainable agriculture could not exist without drainage. Therefore, to ameliorate and prevent soil salinization it is quite necessary to promote the development and application of irrigation and drainage techniques. It is well known that the objective of amelioration and prevention of soil salinization is to maintain sustainable high agricultural productivity of the farmlands. To achieve this objective, the various advanced farming measures should also be adopted.

2.1 The amelioration of saline and alkali lands

Xinjiang autonomous region is with the largest and most serious saline and alkali farmland in the Northwest China. In Xinjiang the saline and alkali land accounts for 77 % of the total suitable cultivated area of 10 million ha. Since the foundation of the People's Republic of China, many measures have been taken to ameliorate the saline and alkali lands in the region, such as developing complete irrigation and drainage systems, developing farmland into strip shape, adopting salt leaching techniques, growing paddy rice, adopting interval cropping pattern of paddy rice and field crops, grazing and pasture. In 1990 Xinjiang developed 10 thousand ha subsurface drainage area by importing subsurface drainage machine and technique from the Netherlands. More than 867 thousands ha of saline and alkali barren lands have been reclaimed in the region. The vast dessert area has been converted into windbreak networks and farming field and pasture area. The Yinchuan plain in Ningxia autonomous region was historically a saline and alkali area. About 50 thousand ha of the saline and alkali land has been reclaimed by diverting water from Yellow River and developing drainage facilities in the region. The average yield can reach as high as 7,500 kg/ha. Ningxia autonomous region is currently implementing a drainage project by importing subsurface drainage machines and technology from the Netherlands.

Huang-Huai-Hai plain, an important agricultural production area in East China, is historically an area with broad distribution of saline-alkali land and frequent natural disasters of drought and waterlogging. The area is characterized with the interval occurrence of waterlogging, salinization and drought. The Chinese government has paid much attention to the development of water conservation projects in the area. The first priority of the planning Water Diverting Project from South to North China will be given to providing water resource to this area. During 1970s comprehensive measures were taken to solve the drought, waterlogging and soil salinization problems in the area. The comprehensive measures included developing well irrigation and well drainage, combining canal irrigation with well irrigation, combining pumped drainage with pumped irrigation from open ditches. and land leveling and soil amelioration. As a result. 2000

thousand ha of saline-alkali land was improved, which accounts for 50 % of the total saline-alkali land in the area. For the purposes of experiment and demonstration, some research organizations established 10 pilot plots in Hebei, Shandong and Jiangsu Provinces. Since 1980 the World Bank and International Foundation for Agricultural Development have frequently sent experts to survey the area. It was acknowledged that the comprehensive measures for saline-alkali land improvement in this area was successful.

China has long coastal lines with large coast saline-alkali area. The eastern coast area and south coast area are predominated with chloride and sulphate soils respectively. In the saline-alkali area with fresh water irrigation condition, saline-alkali soil can be improved by growing paddy rice. For example, in Panjin district of Liaoning Province 133 thousand ha of saline-alkali land was developed into paddy rice field. In this kind of area, if there are perfect irrigation and drainage facilities cotton and other field crops can also be adopted besides paddy rice. For example, in North Jiangsu Province, 120 thousand ha of coastal saline-alkali land has been improved by growing irrigated crops, such as grains and cotton.

The Chinese peasants accumulated plenty of experiences in adoption of the agricultural practices to improve and utilize saline-alkali lands. No matter whether irrigated or rain-fed, proper farming practices and properly applying more organic fertilizers could play an important role on the improvement of saline-alkali lands. Under irrigation condition, good farming practices could not only stabilize the results of saline-alkali land reclamation, but also achieve the goal of increasing crop yields. Under rain-fed condition, better result could also be achieved by adopting good farming practices, such as building the “field ditch”, leveling land and loosening surface soil, etc.

2.2.2 The prevention of secondary soil salinization

Since early of 20th century, modern irrigation and drainage technology have been adopted and extended gradually in China. The extension of modern irrigation and drainage promoted the improvement and amelioration of saline-alkali land in certain extent. In late 1920s, Jinghui, Weihui and Luohui irrigation districts were completed successfully in Shannxi Province. Later on several irrigation projects by diverting water from Yellow River also completed along Yellow River. The potential of soil salinization was existed for most of these irrigation projects due to inadequate consideration of drainage systems. Although the productivity of these irrigation projects was increased significantly, secondary soil salinization occurred in the low-lying area of these irrigation projects only after several years running. Taking Jinghui irrigation project in Shannxi Province as an example, it was completed in 1932 and groundwater table in some area was rising from 10 m to 2 m below surface just after 5 years running. The shallow groundwater table induced the soil salinization in the irrigation district. During the late of 1950s, many irrigation projects and water storage projects on plain by diverting water from Yellow River were completed on the Huang-Huai-Hai plain. Due to insufficient consideration of drainage, secondary soil salinization was occurred at the large area in Hebei, Shandong and Henan Provinces. The saline-alkali area in the region was increased from 1,867 thousand ha to 3,200 thousand ha within 2 to 3 years. The increase of saline-alkali area was preliminarily controlled after 10 years of comprehensive efforts by banning irrigation, controlling irrigation, canal lining, well irrigation and drainage and combining canal irrigation with well irrigation.

Both experiences and lessons were learned in the improvement of saline-alkali lands and prevention of secondary soil salinization in China. Although the natural conditions vary greatly from place to place, the basic principles have been acknowledged to control

soil salinization, i.e. laying equal stress on prevention and amelioration, developing both irrigation and drainage system, taking measures based on the local conditions, adopting comprehensive measures.

3. ~~Technical~~ researches for prevention and amelioration of soil salinization

3.1 ~~Soil~~ water and salt monitoring technology, data collecting and processing system

To monitor and predict dynamic movement of water and salt in the irrigation district with potential of soil salinization, it is necessary to import complete advanced equipment. Technical training is also necessary in order to use the imported equipment properly. The monitoring points for water and salt need to be set up at different types of saline-alkali lands. The monitoring and predicting methods of soil salinization in the irrigation districts need to be studied by both simulation modeling and theoretical analysis.

3.2 ~~Drainage~~ standards and techniques for saline-alkali lands

The following standards and techniques need to be studied:

- a. ~~Controlled~~ standards of the salt contents in soils under different irrigation and drainage measures and conditions;
- b. ~~tolerant~~ indexes of crops to salinity under different climate, soils, groundwater conditions;
- c. ~~controlled~~ dynamic groundwater tables to prevent soil salinization;
- d. ~~comprehensive~~ drainage techniques by combining utilization of open ditches, subsurface pipe and wells;
- e. ~~combining~~ use of new techniques and methods and efficient conventional techniques;
- f. ~~application~~ of new structures, materials, computer and machines;

3.3 ~~The~~ optimal design and operation of drainage system

The following research work need to be carried out:

- a. ~~Optimal~~ design method of the drainage systems with combining use of different drainage measures;
- b. ~~Energy-saving~~ and labor-saving drainage system and structures;
- c. ~~Optimal~~ operation and management of drainage system

3.4 ~~Decision-making~~ support system for prevention of secondary soil salinization in irrigation districts

The threaten of soil salinization problem is serious in the irrigation districts with shallow groundwater, especially in the irrigation districts with frequent gravity irrigation by diverting water from rivers. The dynamic variation and trend of groundwater tables, and accumulation and change of salt in soil need to be monitored closely. Based on the analysis of the collected data, decision-making support system should be developed to predict the potential soil salinization problem, and to provide scientific decisions to solve the problem.

3.5 ~~Reuse~~ of drainage water

The drainage water from the irrigation area with low salinity or brackish groundwater can be reused, especially in dry and water scarce area. The techniques and measures need to be studied to use poor-quality water for irrigation. The impacts of poor-quality water irrigation on crops, soil and groundwater should be studied.

3.6 The techniques for preventing collapse of open ditches with light soil

The open ditches are and will be the predominant drainage facility in China. The collapse of drainage ditches with light soil is very serious problem in China, especially in the area where open ditches are used to drain groundwater. The experiment and researches on prevention of collapse of main and branch ditches have been carried out in China. However, the practical and economical methods and techniques to protect lateral and sub-lateral ditches from collapse are urgently needed.